Towards understanding how young Japanese female college students pronounce the letters of English alphabet

- Part I: general analysis of the formants F1 and F2

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Abstract

This investigation is aimed at getting some insights into how young Japanese female students pronounce the letters of English alphabet. To accomplish it, three different groups of Japanese female students were recruited randomly at a junior college in Japan; namely, a group consisting of students with an ordinary academic background in English language up to high school graduation and currently enrolled in undergrad social sciences course; and two other groups of fresher and sophomore students both majoring in English language and literature course. The formants of each group were analyzed, in which the analysis consisted of statistical testing of the groups against each other as well as a control data set, which was collected by internet downloading the digitalized utterances of native speakers of English chiefly from the US. Moreover, comparison oriented quantitative analysis was carried out in order to figure out whether the data of each individual fitted in the scope of the control data set range, which was assumed to be defined by the mean and standard deviation values of the formants. The results showed that (1) the groups of Japanese students presented similar performances for most of the letters, and (2) nevertheless the groups behaved differently from the control data, some students could well be considered as part of the control set in some cases.

Keywords

(1) English alphabet pronunciation, (2) English sounds, (3) English spoken by Japanese students, (4) formant analysis

1 INTRODUCTION

Pronunciation has been a controversial research paradigm in the history of English language education of non-native speakers with ups and downs just as merry-go-rounds in the sense that from time to time its enthusiastic advocators and those campaigning pro other topics such as teaching grammar have been taking their turns as the predominant school; and consequently each setting the vogue during that prevailing epoch (Jack and Rogers, 2001).

In fact, the last breakthrough bringing out the pronunciation issues to the center of the stage took place in the turn of the last century and triggered a worldwide renewed interest in the role that it potentially plays on the acquisition of English language communication skills. The common denominator of the many related approaches and frameworks developed at the time relied basically on the relationships between intelligibility along with comprehensibility of the utterances and the establishment of some effective communication channels among the speakers (Morley, 1991).

For example, Moore (2001), who targeted learners attending an English language school in an on-site empirical study in Germany, assessed the influence that the explicit remarks and instructions to tune the pronunciation had on the language learning. The outcome of this tentative practical work showed

that improvements in the communication skills were likely to be more prominent in an environment where continuous and direct pieces of advice on the learner's pronunciation were provided during the classes rather than just exposing them passively to the target language, which would be an unavoidable picture in the milieu of factors such as limited course hours and restricted number of teachers in a classroom to assist an even far larger number of students, just to mention a few among countless of other factors and circumstances that would compel teachers to allot a little, if not none, time to spend on training and/or drilling of speech production.

On the other hand, as far as the teaching of English by native speakers of English in Japan is concerned with, they have been integrated since 1987 as non-tenured assistant language teachers (ALT) to being part of the teaching staff at nearly all schools from elementary to high schools throughout the country in order to help Japanese students nurture the feeling of what genuine sounds as spoken in these original English speaking countries are as well as nourish some communication skills in order to be able to interact with foreigner people, inside and outside the country, in English (JET, 2014). In the pronunciation perspective context, there has been publicized a lot of literature on either qualitative or perceptual analysis of the difficulties faced by Japanese learners and recommendations to ALTs on how to handle some of these cases from the non-Japanese teachers standpoint have been proposed ever since (Riney and Hsieh, 1993; Ohata, 2004; Smith, 2012).

Taking into consideration these frameworks, this work is part of an undergoing project to characterize quantitatively the Japanese pronunciation of English sounds based on the physics of the sounds and statistical tools available to process numerical data. So that, a better understanding of the mechanical properties of the sounds will allow one to perform more precise diagnoses of the weaknesses and the primary sources that Japanese students face in their pronunciation of English sounds; and, hopefully, this will help establish some kind of procedure to assist them in their learning processes.

Indeed, our previous preliminary comparative studies on the pronunciation of English vowels by Japanese students have shown sensitive statistical differences in the formants generated along the vocal tracts when benchmarked against native speakers from North America; chiefly the US (Izuta, 2013). Yet, when a correlation testing of these English vowel sounds uttered by Japanese students and a set of Japanese language sounds somehow resembling some of the English phonemes was carried through, the results suggested that despite the visible and apparent efforts by the Japanese students to make the English utterances when instructed to do so, the group as a whole showed an evident tendency to produce voice formants, which leaned toward Japanese sounds rather than its English counterpart (Izuta, 2014).

In this investigation we focused on the Japanese pronunciation of English alphabet and analyzed their formants. Three groups of Japanese female college students and a set of native speakers of English sounds were processed. Two groups consisted of fresher students with one of them with only students from the social sciences department whereas those belonging to the other one were all with the English department. The third group had also only students from the English department but in the second academic year. The analysis consisted of three steps. In the first step, the formants F1 and F2 were filtered out and graphically plotted, from which information on the positioning of the tongue could be read out. The next step was to test for statistical difference of the mean values of these formants. This procedure makes it clear the group behavior as a whole. In the third step, the subjects were seen and tested individually to whether they fell in the range of the data set of native sounds.

Finally, the remainder of the paper is organized as follows: in section 2, the experimental set up is presented in detail; the results are given in section 3; and outcomes are discussed in section 4.

2 EXPERIMENTAL PROTOCOL

In this section, we present the experimental protocol. Basically, two types of measurements were performed. One was the conventional recruitment of subjects and recording of the voice sounds with a computer based data acquisition system. The other one was the downloading of the digital data of interest from the internet.

2.1 Subjects

Three groups of female college students participated in the experiment. The group (EM-2) formed by only second graders of English language department had six subjects whereas the group (EM-1) consisting of only first-year students of the same department embodied ten individuals. The last group, NEM-1, was composed by eight students from the social sciences department.

The students, who were in the range from 18 to 21 years old, all reported having no audio visual impairments or related medical history. Despite the fluency in the regional dialect of their home towns and knowledge of English, none of them spoke any other language other than Japanese.

Unlike the students in NEM-1, who had never been learning English as extracurricular activities in any kind of language schools and alike, the members of EM-1 and EM-2 had not only privately studied English conversation as extracurricular activities outside the conventional schools, but also taken English proficiency tests like TOEIC and also gone to study English in the US participating in short-term English language learning programs.

2.2 Data acquisition

The students were provided with a list containing the English alphabet without the vowels 'a', 'e', 'i', 'o' and 'u', which have already been discussed in our previous reports (Izuta, 2014), and enough time to check the phonetic transcriptions (IPA, 1998) or whatever they wanted to. Then after some training trials, the data recordings and acquisitions were actually performed. During the recordings of the three sessions intended to processing, the subjects kept as possible as their usual speaking rhythm.

The main tool for data acquisition was a 2.5 GHz Intel Pentium personal computer running SoundEngine on Microsoft Windows 7 while connected to a commercial multi-channel sound mixer TASCAM US-322, which had plugged to it an electronic condenser microphone SONY ECM-PCV800.

For data processing of the digital signals, the free software Praat and its functional features were fully explored to generate the text format files of formants, whose physics and measurements techniques were discussed in (Ladefoged, 1993; Titze, 1994; Ladefoged, 2007), to be then statistically processed on Microsoft Excel 2013.

2.3 Collecting the utterances of the native speakers of English

The pronunciation data of the native speakers of English were acquired from a number of web sites over the internet (Cambridge, 2004; Collins, 2014; dictionary.com, 2014; forvo, 2014; howjsay, 2014; Weblio, 2014; thefreedictionary, 2014).

Furthermore, the sounds were carefully selected to make sure that only voices of North American adult female were downloaded. To accomplish it, the sounds were captured from only reliable web sites displaying an explicit statement that the utterances were from someone originally from North America. In the sequel, this data set is called ‘natives’ and ‘control group’ interchangeably without any differences in the meaning.

2.4 Data processing

Once the sounds of the subjects were acquired, the digital signals files were opened with Praat and, whenever possible, the signals of all the three trials were selected to processing as shown in Fig i. In some cases, due to the failure in the measurement and other factors, the individual' data was ruled out of the processing, and the sounds related to this letter were handled with this subject missing.

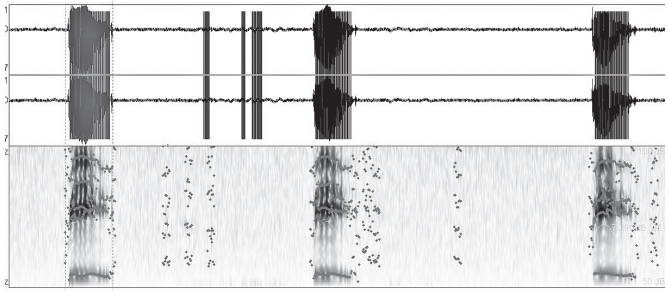

Fig i. Example of a digital utterance file.

The set of data collected for each letter is such that the students repeated the sounds three times; and these three trials were averaged and the mean value was used in the processing procedures that followed. However, when the three trial had discrepant values so that the differences were sensitive to the extent that the audio sound was perceptively distorted, this student's data was left out.

The statistical testing performed hereafter consisted of the analysis of variance of the groups. There were paired up each time and their mean and standard deviation values were used in order to check whether they were from the same data sample.

Furthermore, the data of each individual was tested for the formants F1 and F2 in order to examine whether they fell in the range described in Fig. ii, which means the horizontal interval bounded to the right by mean value of F2 minus its standard deviation, and to the left by F2 plus standard deviation; and the vertical strip with lower bound at mean value of F1 minus its standard deviation, and upper bound at mean of F1 plus the standard deviation. The purpose of this analysis relies on the fact that the statistical testing of the groups provide only information on the relationships between the groups as a whole and nothing about the subjects.

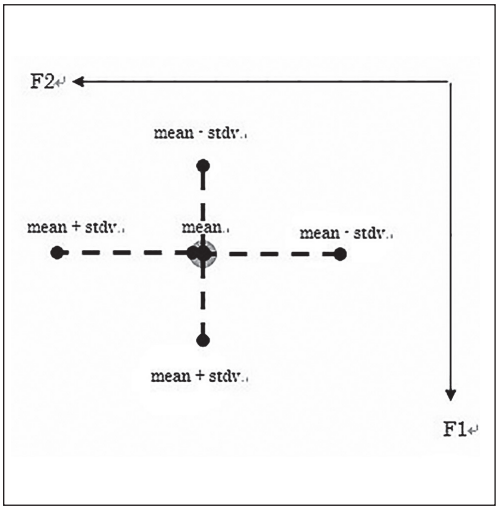

Fig ii. Definition of the scope of the control group.

3 RESULTS

In what follows, the graph of the formants, the statistical testing results and the analysis aimed to check up whether the signals of each individual can be quantitatively considered as an element of group of the native are provided and addressed for each letter.

3.1 Letter B

The formants graph of letter B shown in Fig 1 says that the control data had higher F2 and lower F1 than the students, which had the values horizontally scattered around at 570 Hz of the vertical axis. Interpreting it in the light of the position where the students produced the sounds, they can be characterized relatively to the control data as being 'back/open'.

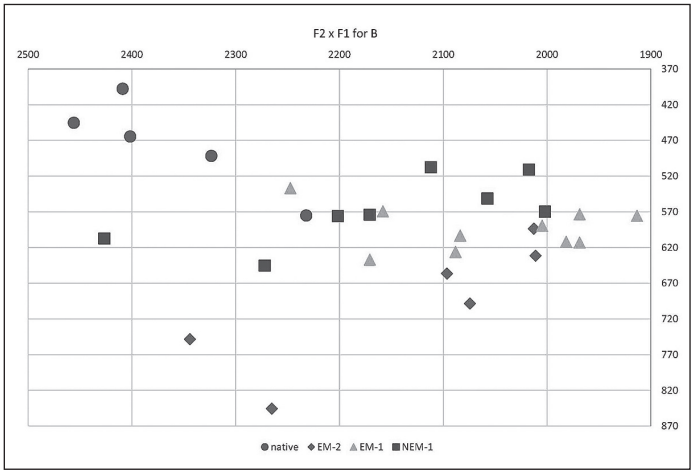

Fig 1. Graph of formants for B. Horizontal axis: F2, vertical axis: F1.

The statistical testing in Fig 2 suggested that, in fact, the students had F1s statistically different from the control group. Interestingly, EM-1 and NEM-1 were not similar for F1 while EM-1 and EM-2 were. Focusing on F2s, the students presented closely related behaviors when paired up, but none of them paired positively with F2 if control group.

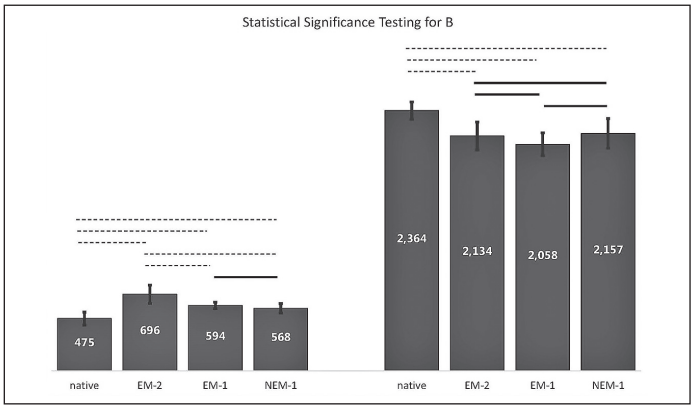

Fig 2. Statistical testing for B. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

Analysis of each subject individually (Fig 3) showed that independent of the groups that the students belonged to, they were not in the range of the values defined by the mean plus minus standard deviation values of the native data set. Note that an individual is considered in the control data range if the formants F1 and F2 are each in the ranges F1 and F2 of the control data, respectively.

INDIVIDUAL ANALYSIS FOR B
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	2364	F2 stdv	79	F1 mean	475	F1 stdv	59

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	no	no	no	no	no	no	yes	no	no
2	yes	no	no	no	no	no	no	yes	no
3	no	no	no	no	no	no	no	no	no
4	no	no	no	no	no	no	no	yes	no
5	no	no	no	no	no	no	no	no	no
6	no	no	no	no	no	no	no	no	no
7				no	no	no	no	no	no
8				no	no	no	no	no	no
9				no	no	no			
10				no	no	no			

Fig 3. Individual Performance for B. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.2 Letter C

The formants F2 of the control data varied from around 2100 to 2400 Hz, whereas F1s where within the interval 550 to 750 Hz (Fig 4). On the other hand the students' F1 ranged from 650 to 1050 Hz, and F2s from 1970 to 2250 Hz. Note that EM-1 with F1 at 1050 Hz could be considered an outlier. On the whole, the students had 'slightly back/ open' characteristics.

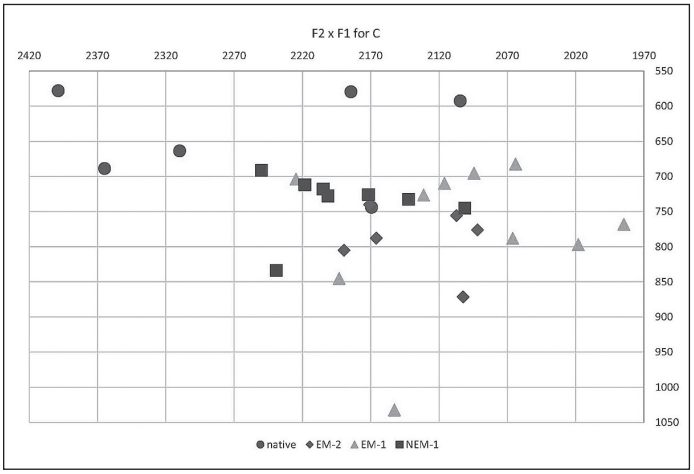

Fig 4. Graph of formants for C. Horizontal axis: F2, vertical axis: F1.

The statistical testing of the groups indicated that, for F1s (Fig 5, left group), none of them had mean value that could be considered from the same sample as the control. But, the mean values of F1s of EM-2 and EM-1, and EM-1 and NEM-1 were pairwise positive. For F2s (Fig 5, right group), NEM-1 and control group, and EM-2 and EM-1 paired positively.

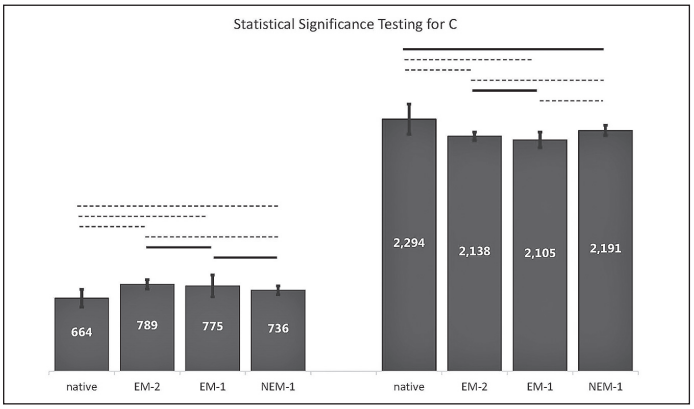

Fig 5. Statistical testing for C. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

Focusing on the results of individual analysis (Fig 6), it showed that nevertheless the groups of students were not statistically similar to control data for F1 with only NEM-1 positive for F2, 1 out of 6 in EM-2, 1 out of 10 in EM-2, and 5 out of 8 in NEM-1 of students had both F1 and F2 values within the range defined by mean plus minus deviation of control data; thus regarded as statistically similar to control.

INDIVIDUAL ANALYSIS FOR C
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	2294	F2 stdv	137	F1 mean	664	F1 stdv	81

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	yes	yes	yes	yes	yes	yes	yes	yes
2	yes	no	no	no	yes	no	yes	yes	yes
3	yes	no	no	no	no	no	yes	yes	yes
4	no	no	no	no	no	no	yes	yes	yes
5	no	no	no	no	no	no	yes	yes	yes
6	no	no	no	yes	no	no	yes	no	no
7				no	yes	no	no	yes	no
8				no	yes	no	no	no	no
9				no	no	no			
10				no	yes	no			

Fig 6. Individual Performance for C. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.3 Letter D

The F2 of the control data were in the interval from 2100 to 2450 Hz which, if the data at 2100 Hz is ruled out, the range changes to from 2250 to 2450 Hz making up a cluster to the students' plots (Fig 7). Apart from the control data F1 at 400 Hz, all the F1 data belonging to the group fitted in the range from 500 to 850 Hz. Thus, the students were relatively to the control 'back/similarly open'.

In fact, the statistical testing corroborated the observation and the results depicted in Fig 7 as can be seen in Fig 8 (left part) for F1, where only EM-2 did not pair positively with control group whereas the other two groups (EM-1 and NEM-1) did. Yet, for the formant F2, the groups of students were statistically similar when paired up, but none of them paired statistically positive with control group.

Testing the individual data to check whether it belonged to the control data group (Fig 9), none of them had F1 and F2 both satisfying the condition for the tested valued be in the range of mean of control data plus minus standard deviation. Note that there were some data included in the control group for either F1 or F2, but not for both F1 and F2.

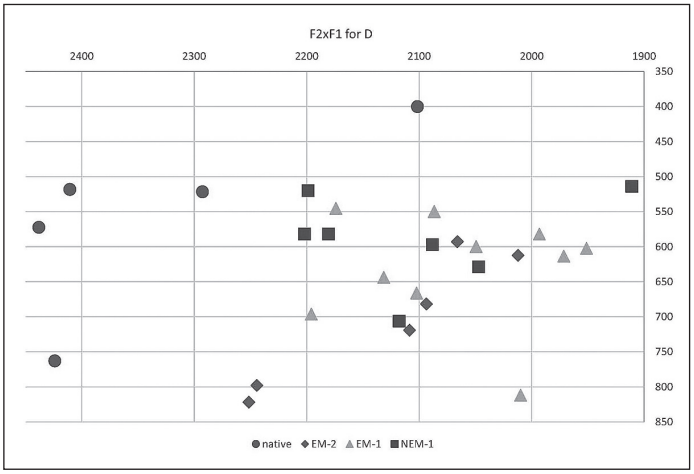

Fig 7. Graph of formants for D. Horizontal axis: F2, vertical axis: F1.

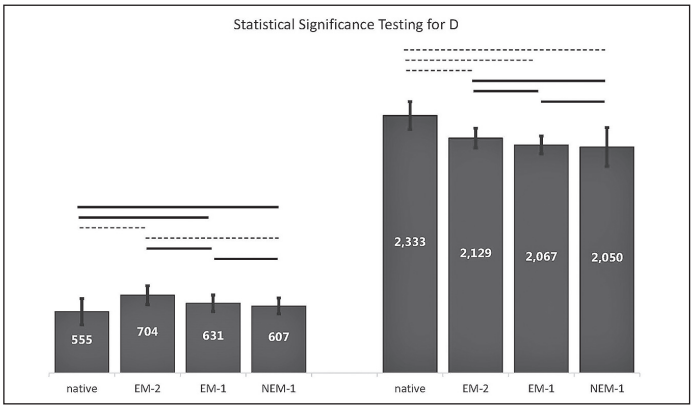

Fig 8. Statistical testing for D. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR D
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	2333	F2 stdv	127	F1 mean	555	F1 stdv	118

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	no	no	no	yes	no	no	no	no
2	yes	no	no	no	no	no	no	yes	no
3	no	yes	no	no	yes	no	no	yes	no
4	no	no	no	no	yes	no	no	yes	no
5	no	yes	no	no	yes	no	no	no	no
6	no	no	no	no	no	no	no	yes	no
7				no	yes	no	no	yes	no
8				no	yes	no	no	yes	no
9				no	yes	no			
10				no	yes	no			

Fig 9. Individual Performance for D. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.4 Letter F

The F2s of the control group were in the spectrum from about 1950 to 2050 Hz, while F1s varied from 850 to 1050 Hz (Fig 10). On the other hand the values of the students spread from 1930 to 2150 Hz for F2, and from 700 to 1200 Hz for F1. Thus, it had not only a single, but at least three characteristics: 'similarly back/ similarly open', 'front/close' and 'front/open'.

Despite this classification based on the direct visual inspection of Fig 10, the statistical testing graphs (Fig 11) supported that as far as F1 (left side) is concerned with, all the groups were statistically pairwise similar, which means the openness of the mouth were in fact similar. However, looking at the comparison results for F2s, the control group paired positively with only EM-1. Yet, the groups of students were similar to each other when taken in pairs.

Individually, 1 out of 6 in EM-2, 4 out of 10 in EM-1, and 2 out of 8 in NEM-1 of students had values of F1 as well as F2 in the range of mean value plus minus standard deviation of control data, when tested for each formant (Fig 12). Note that there were some individuals, who had only F1 or only F2 in the range of the control data.

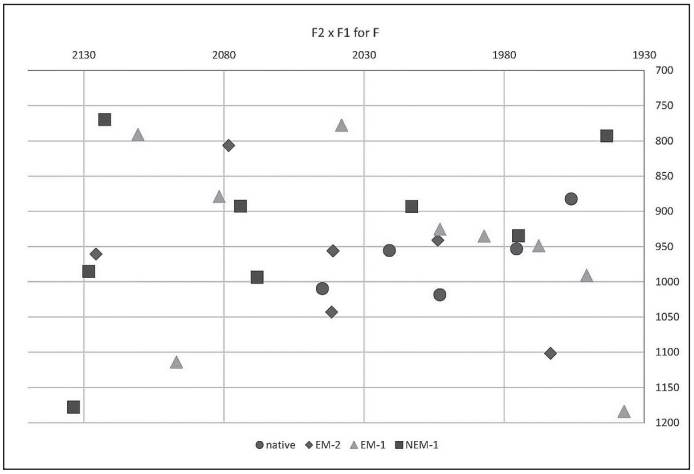

Fig 10. Graph of formants for F. Horizontal axis: F2, vertical axis: F1.

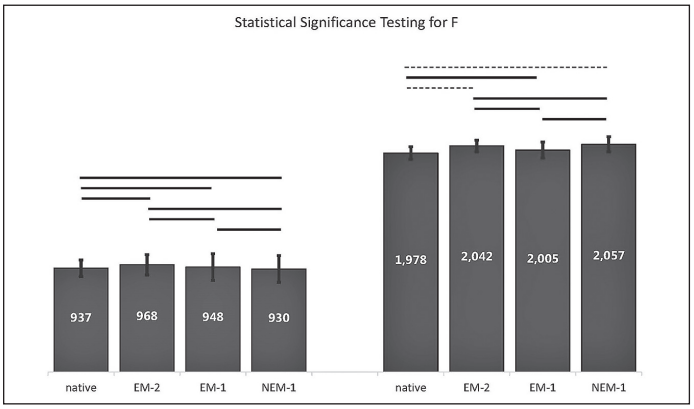

Fig 11. Statistical testing for F. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR F
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	1978	F2 stdv	57	F1 mean	937	F1 stdv	75

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	yes	yes	yes	yes	yes	yes	yes	yes
2	yes	no	no	yes	yes	yes	yes	yes	yes
3	no	yes	no	yes	yes	yes	no	no	no
4	no	no	no	yes	yes	yes	no	yes	no
5	no	yes	no	yes	no	no	no	yes	no
6	no	no	no	no	no	no	no	no	no
7				no	yes	no	no	yes	no
8				no	no	no	yes	no	no
9				no	yes	no			
10				no	no	no			

Fig 12. Individual Performance for F. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.5 Letter G

Fig 13 shows the plots of F2 and F1, and it displays the points of natives having values of F2 greater than 2400 Hz and F1 confined in the interval from 570 to 770 Hz. On the other hand the groups of the students had all values of F2 less than 2400 Hz, and F1 from 530 to 820 Hz. These values allow us to characterize the utterances by the students as being 'back/similarly open'.

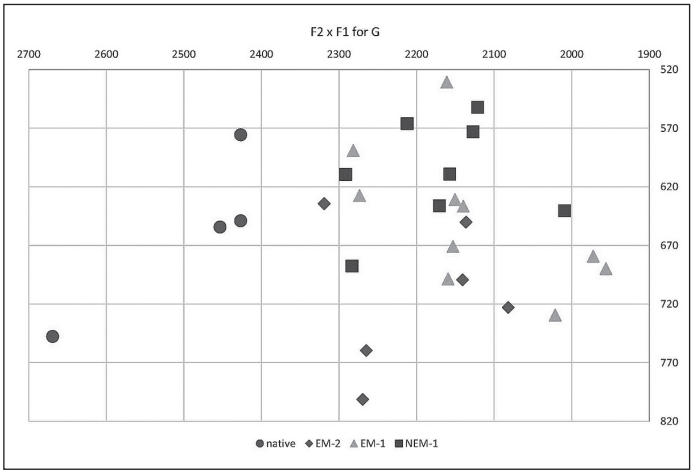

Fig 13. Graph of formants for G. Horizontal axis: F2, vertical axis: F1.

This classification is substantiated with statistical testing as presented in Fig 14. Indeed, from the left part of Fig 14, we had that the control group and the others were statistically similar, but the students groups were not necessarily similar when paired up. The test for F2 (right part of the graph) showed that the group of students were similar when paired as EM-2 and EM-1, EM-2 and NEM-1, and EM-1 and NEM-1, but none of them paired positively with the control group.

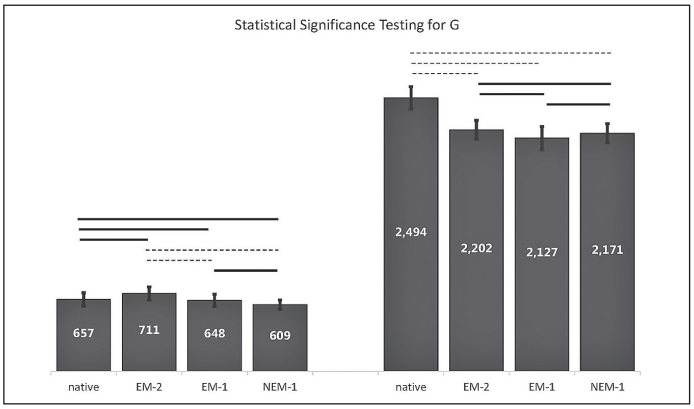

Fig 14. Statistical testing for G. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

The distribution format of the points over the graph shown in Fig 13, in which the range of F2 for the control group and those of students did not intersect, caused the students' values of F2 to fall short of the control group as shown in Fig 15; and as expected, there were some valued of F1 sinking in the group.

INDIVIDUAL ANALYSIS FOR G
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	2494	F2 stdv	102	F1 mean	657	F1 stdv	61

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	no	no	no	no	yes	no	no	yes	no
2	no	no	no	no	yes	no	no	no	no
3	no	yes	no	no	yes	no	no	yes	no
4	no	no	no	no	no	no	no	yes	no
5	no	yes	no	no	yes	no	no	no	no
6	no	yes	no	no	yes	no	no	no	no
7				no	no	no	no	yes	no
8				no	yes	no	no	yes	no
9				no	no	no			
10				no	yes	no			

Fig 15. Individual Performance for G. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.6 Letter H

The graph of formants in Fig 16 shows that F2 of the natives had values varying from 2350 to 2700 Hz, and F1 from 750 to 1150 Hz, but were concentrated in the region of F2 from 2400 to 2600 Hz and F1 from 950 to 1150 Hz. The students tended to be in the area delineated by F2 from 1950 to 2250 Hz and F1 from 750 to 1100 Hz. From these, the students were characterized relatively to the natives as 'back/slightly close'.

Looking at the statistical testing shown in Fig 17, the control group matched statistically with EM-2, but neither with EM-1 nor NEM-1 for F1. Still, EM-2 and EM-1, EM-2 and NEM-1, and EM-1 and NEM-1 were pairwise statistically similar. For F2, the groups of the students were, pretty much as in F1 case, similar; and the control group did not show similarity with any particular group.

Although F2 of the students fell all off the F2 range of the control group, a fair number of F1 fell in the range F1 of the control group as depicted in Fig 18. Actually, 2 out of 6 in EM-2, 4 out of 10 in EM-1, and a half of the students in NEM-1 had verifiably F1 values in the control group, but not F2s in it.

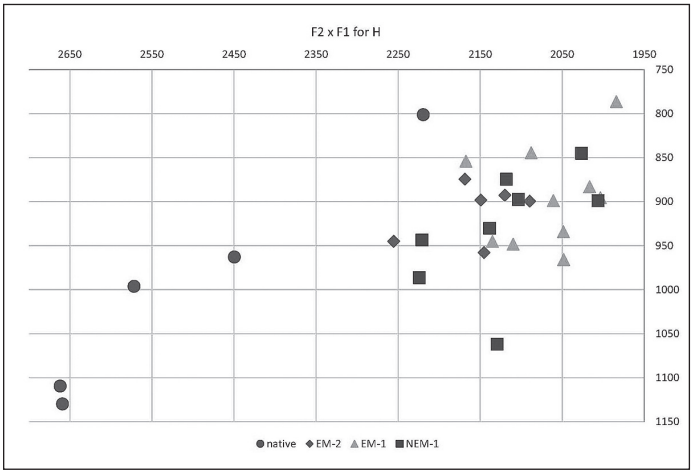

Fig 16. Graph of formants for H. Horizontal axis: F2, vertical axis: F1.

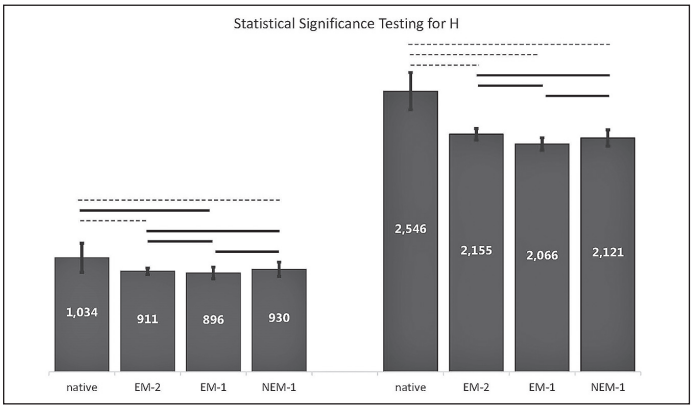

Fig 17. Statistical testing for H. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR H
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	2546	F2 stdv	168	F1 mean	1034	F1 stdv	132

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	no	no	no	no	no	no	no	yes	no
2	no	yes	no	no	yes	no	no	no	no
3	no	no	no	no	yes	no	no	yes	no
4	no	no	no	no	yes	no	no	yes	no
5	no	yes	no	no	no	no	no	no	no
6	no	no	no	no	yes	no	no	yes	no
7				no	no	no	no	no	no
8				no	no	no	no	no	no
9				no	no	no			
10				no	no	no			

Fig 18. Individual Performance for H. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.7 Letter J

The pronunciation of letter J by the natives gravitated from around 2230 to 2500 Hz for F2, and 600 to 850 Hz for F1, where the dispersion of the points on the graph in Fig 19 resembled a linear distribution model of the points. As for the points of the students, F2 hit in the bounds from 1950 to 2250 Hz, and F1 from 550 to 850 Hz. Note that the control data positioned on the left half side of the graph whereas the students on the right half. The characteristic of the students came down to 'back/similarly open'.

The statistical significance testing (Fig 20) showed that F1 of the control group were indeed positively comparable with all other groups when they were paired up just like the duo EM-2 and EM-1 were. On the contrary, the couples of EM-2 and NEN-1, and EM-1 and NEM-1 were not similar. As for F2, only the pairs EM-2 and EM-1, and EM-2 and NEM-1 were positively similar.

Individually testing the students to see whether there would be possible to include them in the control group (Fig 21), nearly all the data came positive only for F1, and none for F2; thus regarded as not from the same sample as the control.

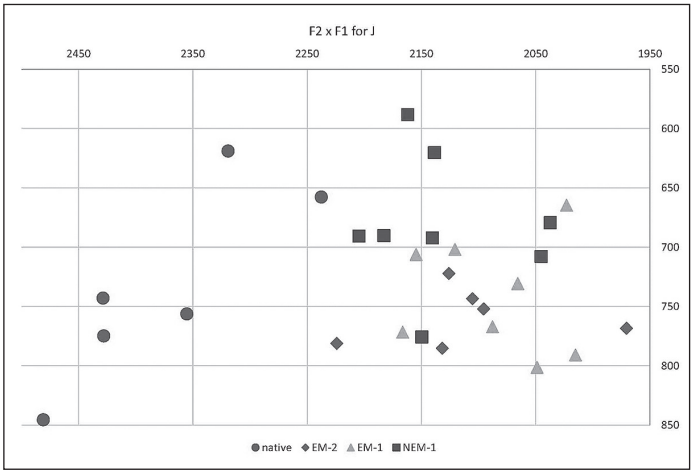

Fig 19. Graph of formants for J. Horizontal axis: F2, vertical axis: F1.

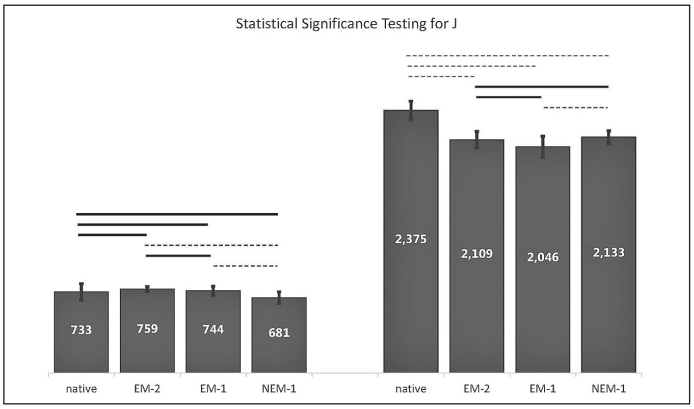

Fig 20. Statistical testing for J. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR J
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	2375	F2 stdv	81	F1 mean	733	F1 stdv	75

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	no	yes	no	no	yes	no	no	yes	no
2	no	yes	no	no	yes	no	no	no	no
3	no	yes	no	no	yes	no	no	yes	no
4	no	yes	no	no	yes	no	no	yes	no
5	no	yes	no	no	yes	no	no	yes	no
6	no	yes	no	no	yes	no	no	yes	no
7				no	yes	no	no	no	no
8				no	yes	no	no	yes	no
9				no	yes	no			
10				no	yes	no			

Fig 21. Individual Performance for J. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.8 Letter K

The formant graph for letter K is as shown in Fig 22, from which we see that F2 generated by the native speakers of English had minimum value close to 2250 Hz and a maximum in the proximity of 2500 Hz, which made up a region on the left upper corner of the graph whereas the students' minimum pointed at around 2000 Hz and the maximum at 2350 Hz bounded an region on the right down area of the graph. Focusing on F1, the range widened from 550 to 850 Hz for the control and from 600 to 850 Hz for the students. Hence the students were featured as 'back/slightly open'.

As a matter of fact, the statistical testing depicted in Fig 23 showed that only the pairs of control group and NEM-1, and EM-2 and EM-1 were statistically similar for F1. For F2, the pairs EM-2 and NEM-1, and EM-1 and NEM-1 were similar, but the other pairs were not.

As a matter of fact, there was only one subject in EM-2 who performed similarly to the control group for F2 as seen in the individual analysis (Fig 24). Contrarily, 1 out of 6 in EM-2, 2 out of 10 in EM-1, and 7 out of 8 in NEM-1 of the students grouped positively with control data set.

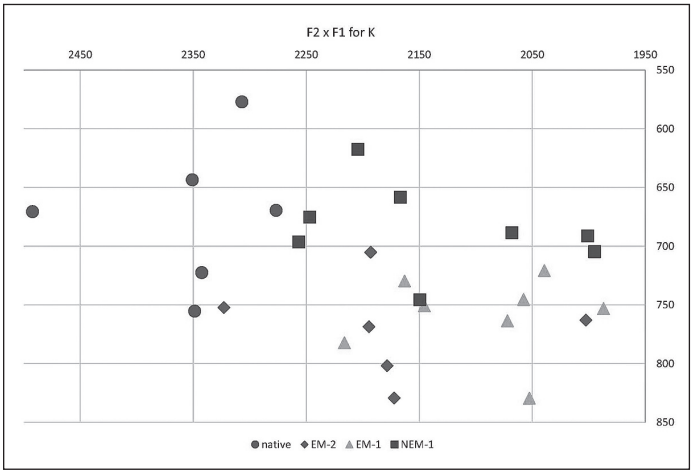

Fig 22. Graph of formants for K. Horizontal axis: F2, vertical axis: F1.

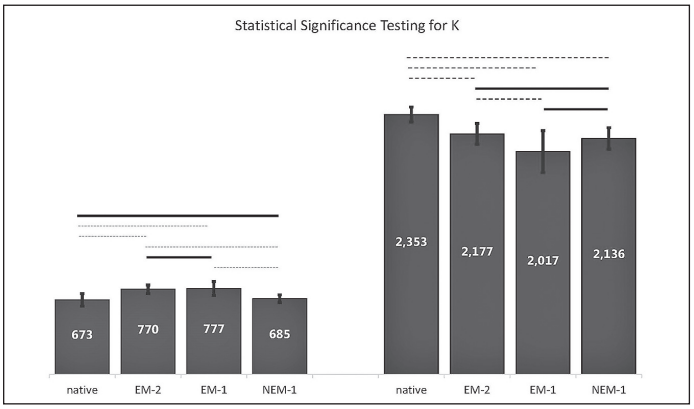

Fig 23. Statistical testing for K. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR K
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	2353	F2 stdv	68	F1 mean	673	F1 stdv	57

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	no	no	no	no	no	no	yes	no
2	no	no	no	no	no	no	no	yes	no
3	no	no	no	no	no	no	no	yes	no
4	no	no	no	no	no	no	no	no	no
5	no	no	no	no	no	no	no	yes	no
6	no	yes	no	no	yes	no	no	yes	no
7				no	no	no	no	yes	no
8				no	no	no	no	yes	no
9				no	no	no			
10				no	yes	no			

Fig 24. Individual Performance for K. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.9 Letter L

Fig 25 illustrates the graph of formants F2 and F1. The data set of the natives located distinctly on a region defined by F2 varying from 1400 to 1700 Hz, and F1 from 600 to 800 Hz. The students dispersed on a rectangular region traced up by F2 from 1700 to 2400 Hz, and F1 from 550 to 850 Hz with the groups making up very clear clusters on the graph in the sense that NEM-1 would be said 'front/close' whereas NEM-2 and NEM-1 would be both characterized as 'front/open'.

This common feature of EM-2 and EM-1 reflected the statistical similarity of these two groups for F1 as well as F2 as expressed in Fig 26. In addition, nevertheless the 'openness' of the control group and EM-2 as well as EM-1 seemed to be somehow alike on the Fig 25, the statistical testing of them for F1 did not support this visual observation. F2 testing confirmed the previous mention on the region of positioning of the points, which showed a division between the control and students.

Actually, due to this divide, none of the students could be viewed as coming out of the control group when analyzed individually for this possibility (Fig 27).

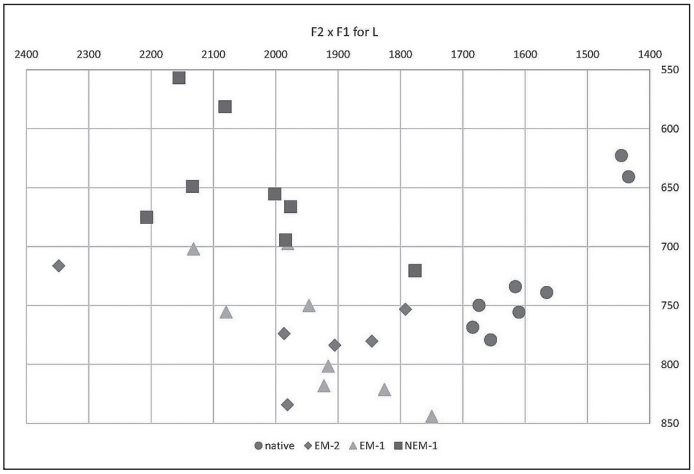

Fig 25. Graph of formants for L. Horizontal axis: F2, vertical axis: F1.

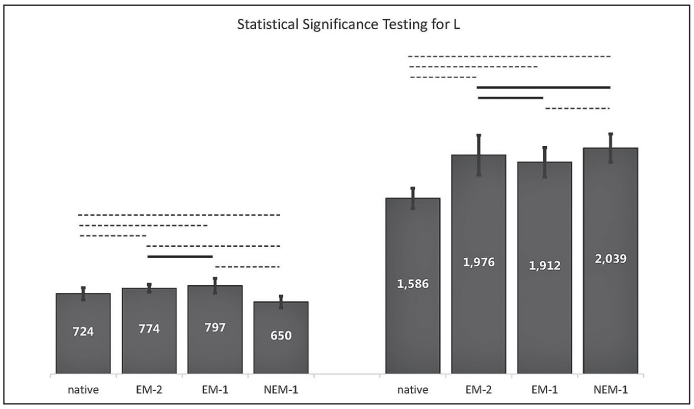

Fig 26. Statistical testing for L. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR L
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	1586	F2 stdv	91	F1 mean	724	F1 stdv	55

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	no	no	no	yes	no	no	no	no	no
2	no	no	no	no	yes	no	no	yes	no
3	no	yes	no	no	no	no	no	yes	no
4	no	no	no	no	yes	no	no	no	no
5	no	yes	no	no	yes	no	no	no	no
6	no	yes	no	no	no	no	no	no	no
7				no	no	no	no	yes	no
8				no	no	no	no	no	no
9				no	no	no			
10				no	yes	no			

Fig 27. Individual Performance for L. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.10 Letter M

Fig 28 reveals that the natives had F2 varying from 1750 to 2050 Hz whereas the students were a bit farther from 1850 to 2150 Hz. The values for F1 were between 550 to 700 Hz for natives and between 550 to 1050 for students, with NEM-1 being mainly in the band from 550 to 750 Hz, and the students in ME-2 and ME-1 spread out on the strip. From these, two patterns were singled out: one for NEM-1, which was 'slightly back/similarly open'; and another one for EM-2 and EM-1, which was 'front/open'.

In fact, statistical testing for F1 unveiled that the control group and NEM-1 were similar, as were EM-2 and EM-1 (Fig 29). Looking at F2, the control group did not pair positively with any of the groups of students. On the other hand, the groups of students were all statistically similar for F2 when taken in pairs and tested.

Now, Fig 30 shows that 2 out of 8 students in NEM-1 could be included in the control group whereas EM-2 and EM-1 had no equivalent elements. However, EM-2 as well as EM-1 did have elements with either F2 or F1 related positively with the control group.

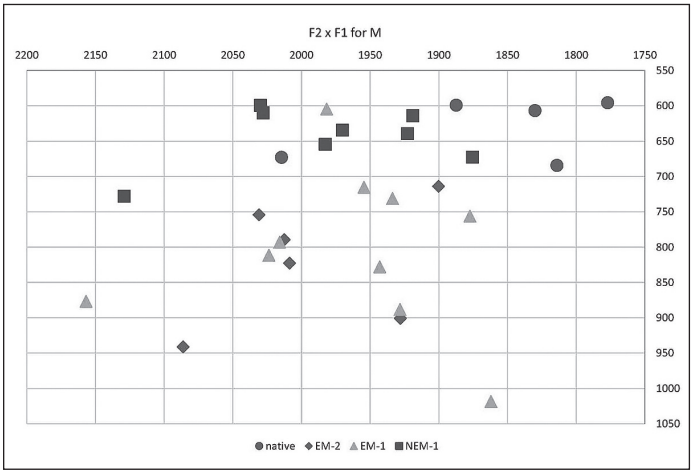

Fig 28. Graph of formants for M. Horizontal axis: F2, vertical axis: F1.

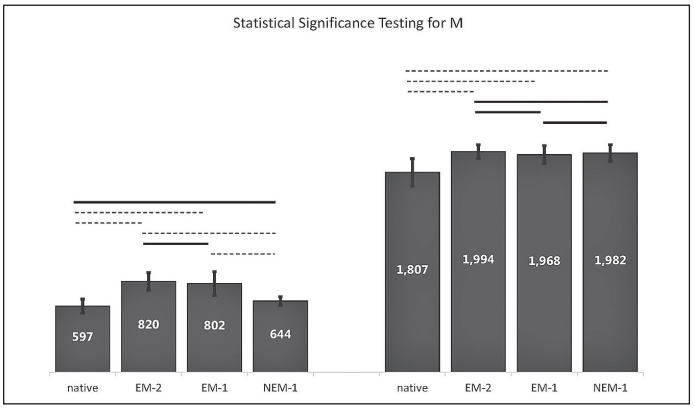

Fig 29. Statistical testing for M. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR M
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	1807	F2 stdv	124	F1 mean	597	F1 stdv	63

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	no	no	yes	no	no	yes	yes	yes
2	no	no	no	no	yes	no	yes	yes	yes
3	yes	no	no	no	no	no	yes	no	no
4	no	no	no	no	no	no	no	yes	no
5	no	no	no	no	no	no	no	yes	no
6	no	no	no	no	no	no	no	no	no
7				yes	no	no	no	yes	no
8				no	no	no	no	yes	no
9				yes	no	no			
10				no	no	no			

Fig 30. Individual Performance for M. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.11 Letter N

The formats F2 produced by natives had values from 1800 to 2050 Hz, and the students from 1830 to 2200 Hz, in which the latter located a bit farther than the former (Fig 31). As for F1, the natives stayed within the range from 500 to 700 Hz, and the students from 550 to 900 Hz. These provided three patterns; namely, 'slightly front/open' for EM-2, 'similarly between front and back/open' for EM-1, and 'similarly between front and back/ similarly semi-open' for NEM-2.

In the light of statistical testing (Fig 32), as for F1, EM-2 and EM-1 presented statistical similarity, but not the control group paired up with any of the groups of students, which taught that despite the proximity of the control and NEM-1 groups perceived visually Fig 31, they were not statistically similar. For F2, the control group paired up with each group of students separately were all similar. Actually, only the combination EM-2 and EM-1 was considered not similar.

Fig 33 means that EM-2 did not include members who could be considered as part of the control group whereas EM-1 had one, and NEM-1 had two students who could be seen as so.

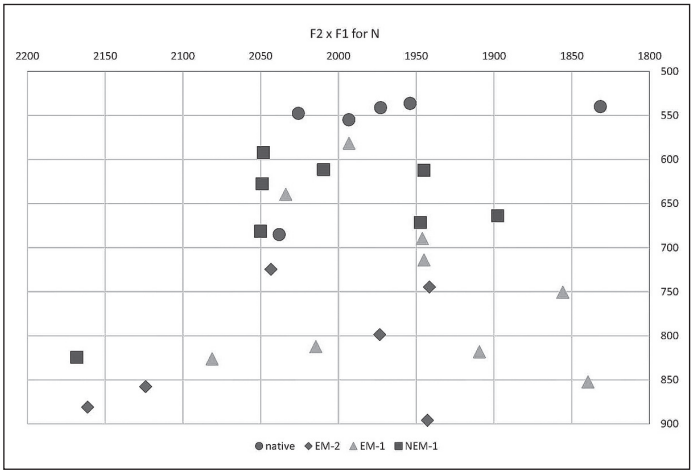

Fig 31. Graph of formants for N. Horizontal axis: F2, vertical axis: F1.

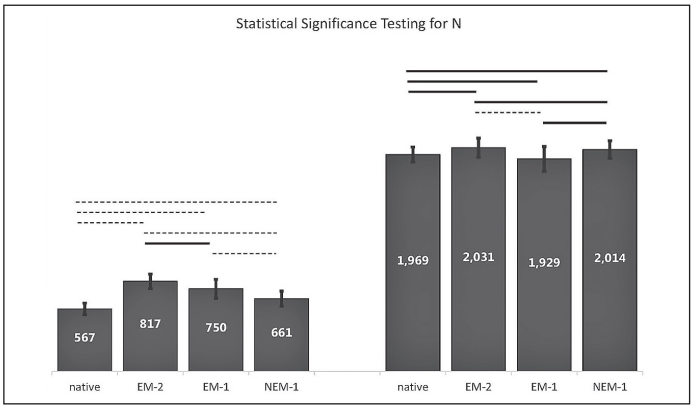

Fig 32. Statistical testing for N. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR N
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	1969	F2 stdv	68	F1 mean	567	F1 stdv	53

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	no	no	yes	yes	yes	yes	yes	yes
2	yes	no	no	no	no	no	yes	yes	yes
3	yes	no	no	no	no	no	yes	no	no
4	no	no	no	no	no	no	no	yes	no
5	no	no	no	yes	no	no	no	no	no
6	no	no	no	yes	no	no	no	no	no
7				yes	no	no	no	no	no
8				yes	no	no	no	no	no
9				no	no	no			
10				yes	no	no			

Fig 33. Individual Performance for N. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.12 Letter P

As seen in Fig 34, F2 of natives located in the strip from 2300 to 2550 Hz, and F1 from 400 to 600 Hz; F2 of EM-2 was left bounded at around 1950 Hz and right at 2250 Hz; and its F1 was from 630 to 800 Hz. By the way, the region of EM-1 on the graph pretty much overlapped the one of EM-2. Differently, NEM-1 had F2 running from 1950 to 2400 Hz and F1 from 480 to 650 Hz with the point at F2 assuming the value nearby 2400 Hz could be considered an outlier. From these, the students were taken to be 'back/open'.

From the statistical testing shown in Fig 35, we learned that neither F1 nor F2 suggested any statistical similarity between the control group and the others when paired up. Moreover, EM-2 and EM-1 were similar for both F1 and F2. Finally, EM-2 and NEM-1, and EM-1 and NEM-1 were similar for F2.

Seeing the subjects individually (Fig 36), neither EM-2 nor EM-1 had any elements with either F1 or F2 which could be considered in the scope of the control group. Unlikely, NEM-1 had elements with either F1 or F2 assignable to the control group, but had no elements with both F1 and F2 satisfying the inclusion condition.

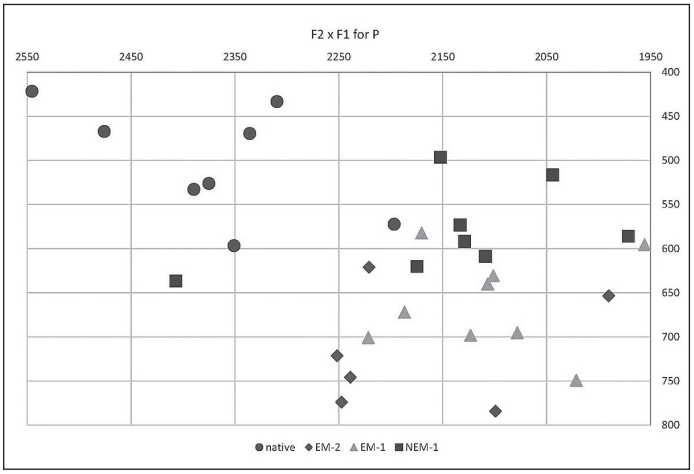

Fig 34. Graph of formants for P. Horizontal axis: F2, vertical axis: F1.

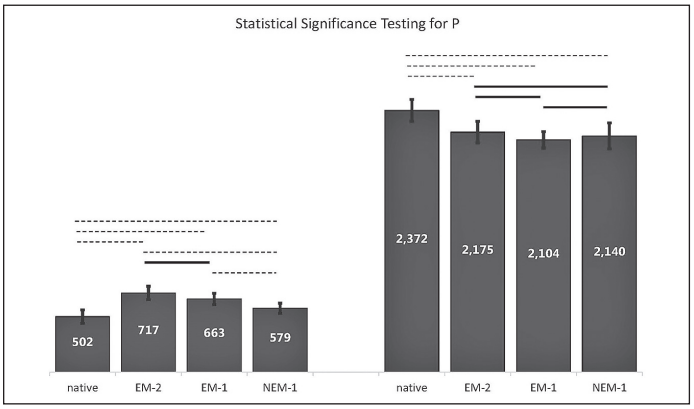

Fig 35. Statistical testing for P. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR P
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	2372	F2 stdv	98	F1 mean	502	F1 stdv	60

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	no	no	no	no	no	no	yes	no	no
2	no	no	no	no		no	no	yes	no
3	no	no	no	no	no	no	no	no	no
4	no	no	no	no	no	no	no	no	no
5	no	no	no	no	no	no	no	no	no
6	no	no	no	no	no	no	no	yes	no
7				no	no	no	no	no	no
8				no	no	no	no	no	no
9				no	no	no			
10				no	no	no			

Fig 36. Individual Performance for P. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.13 Letter Q

The letter Q pronounced by the native speakers of English had F2 in a wide area ranging from 1800 to 2280 Hz; and F1 from 530 to 800 Hz. And the points belonging to the students scattered in a region bounded by the one spanned by the natives. The points of the students did not show any specific cluster like gathering behavior for the groups. So, 'similarly between front and back/ similarly open' was the characteristic of the students.

Fig 38 means that the control group paired up with either EM-2 or EM-1 or NEM-1 were all statistically similar for both of the formants F1 and F2, which confirmed the tendency captured visually from Fig 37. Furthermore, EM-2 and EM-1 were similar for F1 and F2, but EM-2 and NEM-1, and EM-1 and NEM-1 were not similar for neither F1 nor F2.

However, the similarity of the groups of students to the control group did not mean that all the students behaved as the elements of the control group as shown in Fig 39. In fact, 3 students in EM-2, 2 students in EM-1, and 3 students in NEM-1 were not recognized as potential members of the control group.

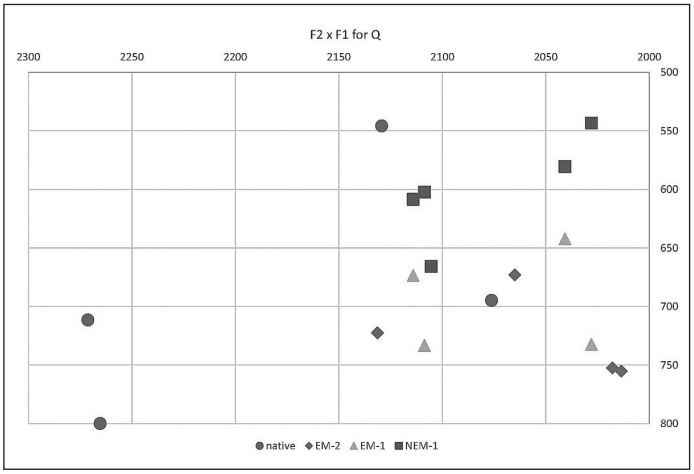

Fig 37. Graph of formants for Q. Horizontal axis: F2, vertical axis: F1.

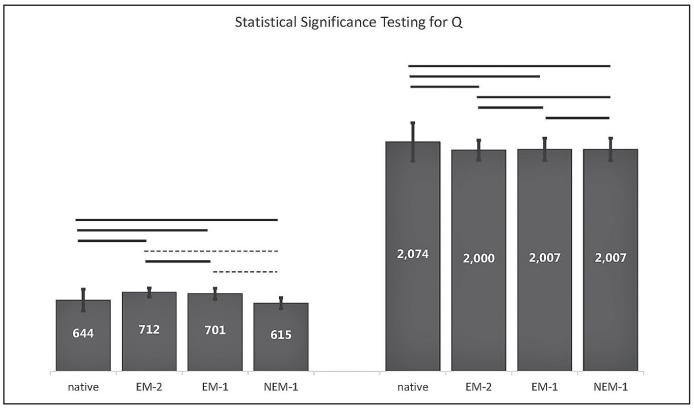

Fig 38. Statistical testing for Q. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR Q
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	2074	F2 stdv	173	F1 mean	644	F1 stdv	97

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	yes	yes	yes	yes	yes	yes	yes	yes
2	yes	yes	yes	yes	yes	yes	yes	yes	yes
3	yes	yes	yes	yes	yes	yes	yes	yes	yes
4	yes	no	no	yes	yes	yes	yes	yes	yes
5	yes	no	no	yes	yes	yes	yes	yes	yes
6	no	yes	no	yes	yes	yes	no	yes	no
7				no	yes	no	yes	no	no
8				no	yes	no	no	yes	no
9									
10									

Fig 39. Individual Performance for Q. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.14 Letter R

As depicted in Fig 40, there formed a cluster of points of the natives around F2 from 1500 to 1630 Hz, and F1 from 750 to 850 Hz, if the point with F2 valued at 1730 Hz is ruled out. Yet, EM-2 was bunched up around F2 from 1580 to 1630 Hz, and F1 from 850 to 970 Hz. In addition, F2 of EM-1 ranged from 1450 to 1770 Hz, and F1 from 750 to 930 Hz whereas F2 from NEM-1 varying from 1500 to 1850 Hz.

The statistical testing illustrated in Fig 41 showed that the control group paired with EM-1, and EM-2 and EM-1 each time were statistically similar for both F1 and F2. Yet, control group versus EM-2, control group versus NEM-1, EM-2 versus NEM-1, and EM-1 versus NEM-1 were not similar for F1. For F2, in addition to the pairs previously cited, all the remaining combinations were also similar.

However, looking closely to each individual, Fig 42 indicated that only 2 students in EM-2 could in fact be seen as part of the control group, and EM-1 would yield only one student with the range of the control. Finally, NEM-1 gave 3 students with values within the range of the control.

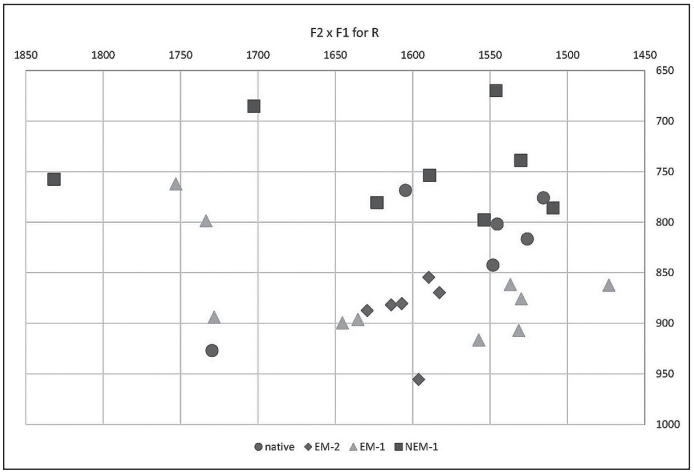

Fig 40. Graph of formants for R. Horizontal axis: F2, vertical axis: F1.

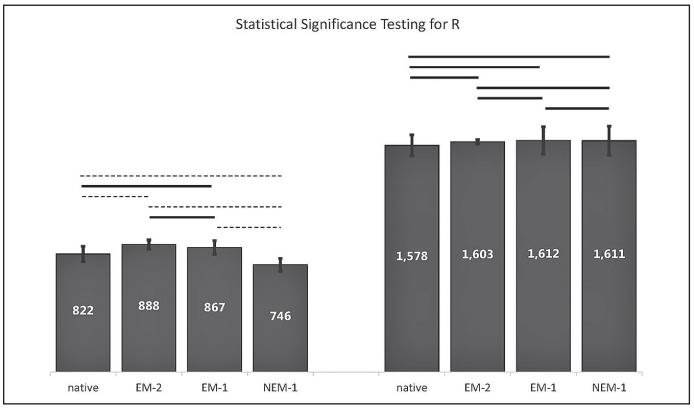

Fig 41. Statistical testing for R. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR R
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	1578	F2 stdv	73	F1 mean	822	F1 stdv	53

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	yes	yes	yes	yes	yes	yes	yes	yes
2	yes	yes	yes	yes	no	no	yes	yes	yes
3	yes	no	no	yes	no	no	yes	yes	yes
4	yes	no	no	no	yes	no	yes	no	no
5	yes	no	no	yes	no	no	no	no	no
6	yes	no	no	no	no	no	yes	no	no
7				yes	no	no	yes	no	no
8				no	yes	no	no	no	no
9				yes	no	no			
10				no	no	no			

Fig 42. Individual Performance for R. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.15 Letter S

If the most left data of the natives with F2 in the proximity of 2130 Hz and F1 around 930 Hz as in Fig 43 is an outlier, all other points of the control group is clustered in a region with F2 from 1930 to 2030 Hz, and F1 from 780 to 930 Hz. F2 of EM-2 housed in the range from 1950 to 2100 Hz, and F1 from 800 to 1000 Hz. And the points of EM-1 dispersed from 1950 to 2180 Hz for F2, and 850 to 1180 Hz for F1. Yet, F2 of NEM-1 varied from 1930 to 2180 Hz with F1 from 730 to 1030 Hz. In overall, the pattern of the students was 'front/open'.

The behavior of the groups in relation to each other showed in Fig 44 says that the control group and NEM-1, EM-2 and EM-1, and EM-2 and NEM-1 were statistically similar for F1. As for F2, this similarity was found when the control group and EM-2, EM-2 and EM-1, EM-2 and NEM-1, and EM-1 and NEM-1 were paired up.

From the individual analysis, EM-2 had no subjects performing within the ranges of the control group. However, EM-1 did include one element whereas NEM-1 had 3 students in the vicinity of the mean values of the control group as showed in Fig 45.

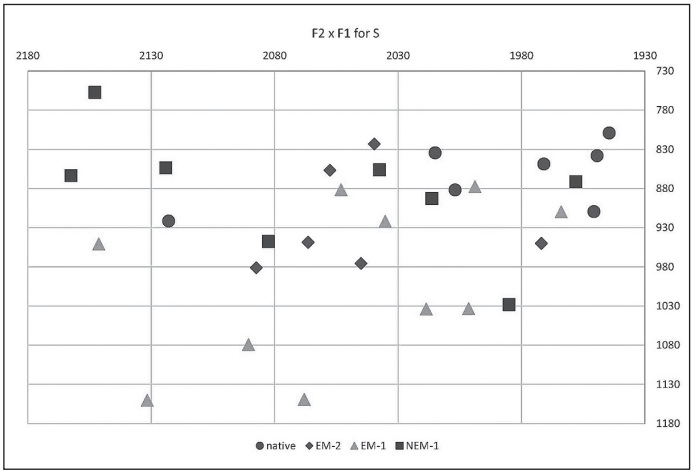

Fig 43. Graph of formants for S. Horizontal axis: F2, vertical axis: F1.

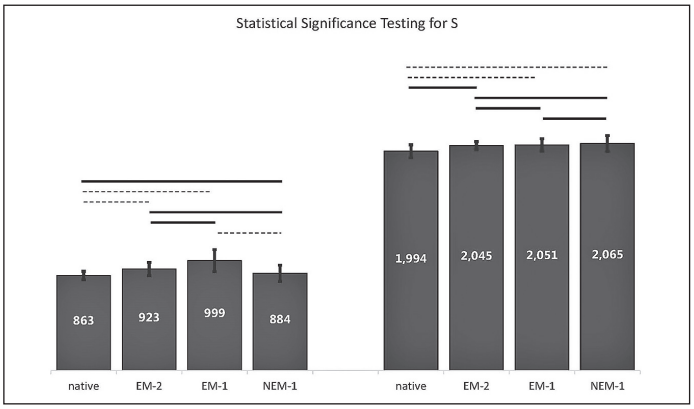

Fig 44. Statistical testing for S. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR S
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	1994	F2 stdv	59	F1 mean	863	F1 stdv	39

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	no	no	yes	yes	yes	yes	yes	yes
2	no	no	no	no	no	no	yes	yes	yes
3	yes	no	no	no	no	no	yes	yes	yes
4	yes	no	no	no	no	no	yes	no	no
5	no	no	no	no	no	no	no	no	no
6	no	yes	no	yes	no	no	no	yes	no
7				no	yes	no	no	no	no
8				yes	no	no	no	yes	no
9				yes	no	no			
10				yes	no	no			

Fig 45. Individual Performance for S. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.16 Letter T

Fig 46 shows that F2s of natives, with exception of rightmost point, were greater than 2300 Hz and going up to 2650 Hz; and F1 changed from 450 Hz up to 680 Hz. For the students, EM-2 had F2s between 1900 and 2350 Hz, and F1s between 650 and 800 Hz. Furthermore, the region of points of EM-1 were overlapping the one defined by these points of EM-2. Now, F2s of NEM-1 fell in the interval starting at around 1950 to 2400 Hz, and F1 from 500 to 650 Hz. In general the students were 'back/slightly open'.

Testing statistically the F1s of the groups, control group and NEM-1, and EM-2 and EM-1 were positively similar whereas the pairs of the control versus EM-2, control versus EM-1, EM-2 versus NEM-1, and EM-1 versus NEM-1 came up negative. The results for F2 showed that the control versus the group of students taken in pairs were negative whereas the group of students when paired up were positive.

The analysis of the individuals shown in Fig 48 says that no students in EM-2 as well as EM-1 were in the scope of the control group. On the other hand, two students in NEM-1 got in the group.

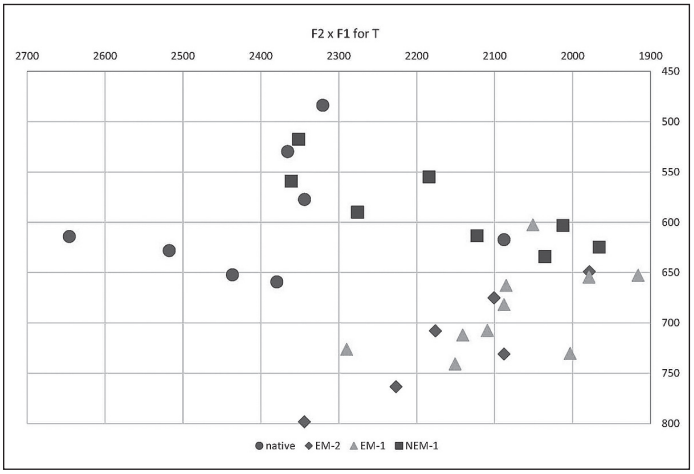

Fig 46. Graph of formants for T. Horizontal axis: F2, vertical axis: F1.

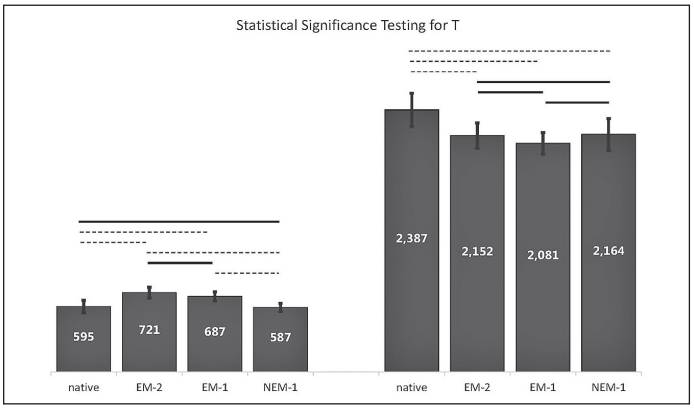

Fig 47. Statistical testing for T. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR T
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	2387	F2 stdv	151	F1 mean	595	F1 stdv	57

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	no	no	no	yes	no	no	yes	yes	yes
2	yes	no	no	no	no	no	yes	yes	yes
3	no	no	no	no	no	no	no	yes	no
4	no	no	no	no	yes	no	no	yes	no
5	no	yes	no	no	no	no	no	yes	no
6	no	no	no	no	no	no	no	yes	no
7				no	no	no	yes	no	no
8				no	no	no	no	yes	no
9				no	no	no			
10				no	no	no			

Fig 48. Individual Performance for T. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.17 Letter V

The pronunciation of fricative sound V had F2 for the natives from 2150 to 2430 Hz, and F1 from 420 to 650 Hz, where considering the rightmost point as an outlier, the points would cluster in the upper left region of Fig 49. EM-2 presented F2 from 1980 to 2320 Hz, and F1 from 550 to 750 Hz. EM-1 and NEM-1 agglomerated in a region bounded by F2 from 1950 to 2180 Hz, and F1 from 550 to 750 Hz. In overall, the pattern of the students boiled down to 'back/open'.

The relationship between these clusters are described in Fig 50. For F1, the control group did not related with any of the groups of students whereas pairwise testing of these groups of students turned out positive. Furthermore, the control group and other groups did not end up positive for F2, either. Only EM-1 and NEM-1 were statistically similar when he groups of students were paired up.

The results of individual analysis depicted in Fig 51 showed that there were students in EM-2 within the scope of the control group for either F1 or F2, but not for both of them. Contrarily, EM-1 and NEM-1 had subjects with only F1 fulfilling the inclusion condition.

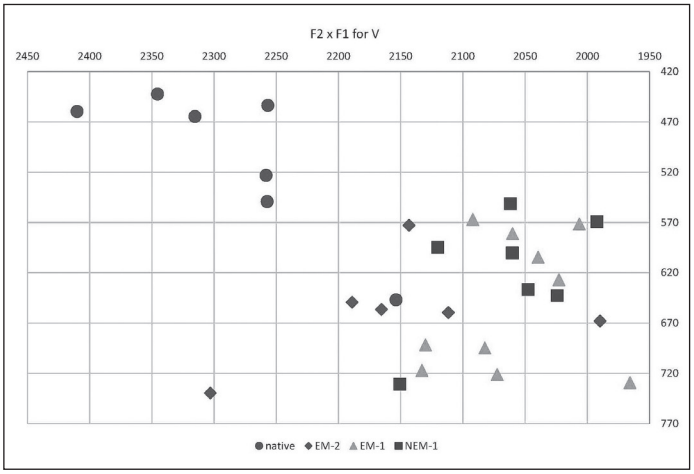

Fig 49. Graph of formants for V. Horizontal axis: F2, vertical axis: F1.

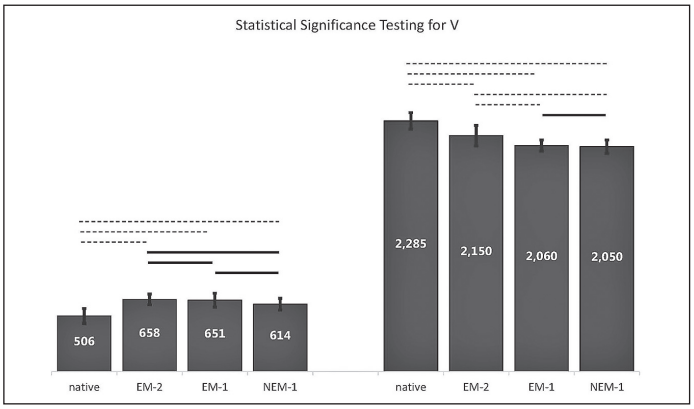

Fig 50. Statistical testing for V. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR V
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	2285	F2 stdv	75	F1 mean	506	F1 stdv	68

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	no	no	no	no	no	no	no	no
2	no	no	no	no	no	no	no	no	no
3	no	no	no	no	yes	no	no	yes	no
4	no	no	no	no	no	no	no	no	no
5	no	no	no	no	no	no	no	no	no
6	no	yes	no	no	no	no	no	yes	no
7				no	yes	no	no	no	no
8				no	no	no	no	no	no
9				no	no	no			
10				no	no	no			

Fig 51. Individual Performance for V. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.18 Letter W

The number of native subjects for W was 4 persons, and as displayed in Fig 52, their region was defined by F2 from 1730 to 1930 Hz, and F1 from 470 to 600 Hz. The regions of EM-2 and EM-1 overlapped and were circumscribed around by F2 from 1880 to 2030 Hz, and F1 from 550 to 870 Hz. On the other hand, F2 of NEM-1 varied from 1780 to 2080 Hz, and F1 from 520 to 750 Hz. Thus the dominant pattern of the points belonging to the group of students was 'front/open'.

Centering the attention to the statistical significance testing, Fig 53 says that the control group did not show similarity with the groups of students for F1 when paired up with each other. For the groups of students, unlike the pairs of EM-2 versus NEM-1 and EM-1 versus NEM-1 that were not statistically similar, the pair of EM-2 and EM-1 was positively related. For F2, the control group versus NEM-1, and the pairwise combination of groups of students were similar.

Fig 54 tells us that none of the members of neither EM-2 nor EM-1 were recognized as in the scope of the control group, but two students of NEM-1 were.

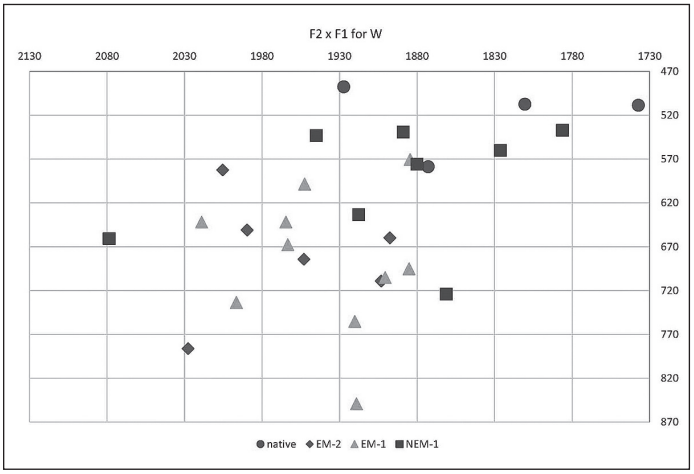

Fig 52. Graph of formants for W. Horizontal axis: F2, vertical axis: F1.

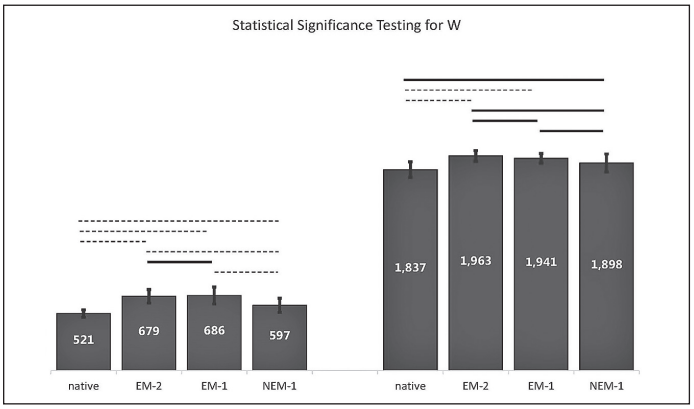

Fig 53. Statistical testing for W. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR W
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	1837	F2 stdv	71	F1 mean	521	F1 stdv	35

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	no	no	yes	no	no	yes	yes	yes
2	no	no	no	yes	no	no	yes	yes	yes
3	no	no	no	no	no	no	yes	no	no
4	yes	no	no	no	no	no	no	no	no
5	no	no	no	no	no	no	no	yes	no
6	no	no	no	no	no	no	yes	no	no
7				yes	no	no	yes	no	no
8				no	no	no	no	no	no
9				no	no	no			
10				no	no	no			

Fig 54. Individual Performance for W. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.19 Letter X

As illustrated in Fig 55, F2 of the natives ran from 2000 up to 2180 Hz, and F1 from 850 up to 1100 Hz. In addition, EM-2 had F2 running from 2000 up to 2100 Hz, and F1 from 930 to 1030 Hz; F2 of EM-1 assuming values in the interval from 1940 to 2130 Hz, and F1 from 850 to 1100 Hz; F2 of NEM-1 from 1930 to 2080 Hz, and F1 from 850 to 1070 Hz. In overall, the students had a 'slightly back/ similarly open' pattern.

From the statistical testing of the groups, which is portrayed in Fig 56, it is clear that all the possible pairings of the groups were statistically similar for F1. However, for F2, control group versus NEM-1, and control group versus EM-1 came up negative to the statistical similarity.

Scrutinizing the data of each individual provided Fig 57, which shows that 4 out of 6 members of EM-2, 4 out of 6 students of EM-1, and 2 out of 8 subjects of NEM-1 came positive, showing that these elements were in the scope of the control group for both F1 and F2 ranges. Note that nevertheless EM-2, as a group, was statistically similar to the control group, two elements did not fit in the scope of the control group.

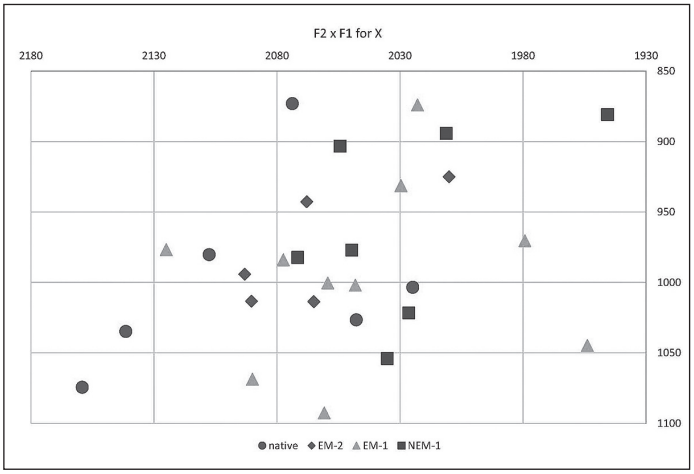

Fig 55. Graph of formants for X. Horizontal axis: F2, vertical axis: F1.

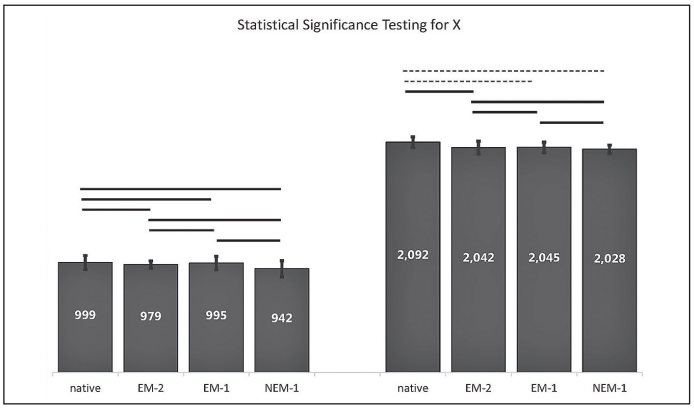

Fig 56. Statistical testing for X. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR X
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	2092	F2 stdv	48	F1 mean	999	F1 stdv	63

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	yes	yes	yes	yes	yes	yes	yes	yes
2	yes	yes	yes	yes	yes	yes	yes	yes	yes
3	yes	yes	yes	yes	yes	yes	no	yes	no
4	yes	yes	yes	yes	yes	yes	no	no	no
5	no	yes	no	no	yes	no	yes	no	no
6	no	no	no	yes	no	no	no	yes	no
7				no	yes	no	no	no	no
8				no	no	no	no	no	no
9				no	no	no			
10				yes	no	no			

Fig 57. Individual Performance for X. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.20 Letter Y

As exhibited in Fig 58, F2 of the natives had the minimum value around 1600 Hz and the maximum around 1830 Hz, and lower limit of F1 was 630 Hz and upper limit around 900 Hz. Like EM-2, EM-1 had right bound at around 1650 Hz and left at around 1900 Hz for F2, and lower limit at around 700 Hz and upper limit at around 900 Hz. On the other hand, NEM-1 had F2 restricted to the range from around 1680 to 2000 Hz, and F1 from 680 to 880 Hz with the leftmost point being somehow an outlier. The distribution of the students' points had 'similarly between front and back/slightly open' pattern.

Analyzing this pattern on the basis of the statistical testing, the results were as in Fig 59, which shows that, except for NEM-1, the control group did not correlate with the groups of students for F1 when paired up. However, these pairing up combinations were similar for F2.

As a matter of fact, two member of EM-2, two students in EM-1, and three subjects from NEM-1 were admitted to having values in the scope of the control group. Note that there were other students with either F1 or F2, but not both, who fell in the limits of control group.

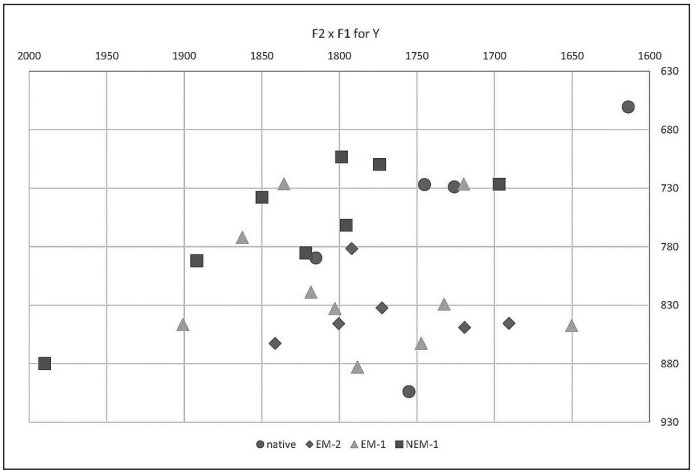

Fig 58. Graph of formants for Y. Horizontal axis: F2, vertical axis: F1.

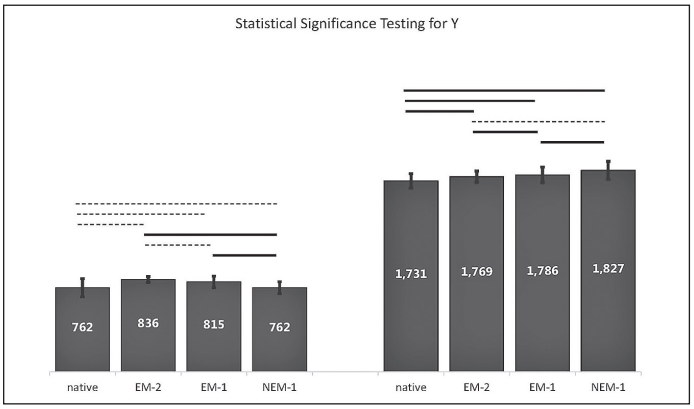

Fig 59. Statistical testing for Y. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR Y
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	1731	F2 stdv	66	F1 mean	762	F1 stdv	82

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	yes	yes	yes	yes	yes	yes	yes	yes
2	yes	yes	yes	yes	yes	yes	yes	yes	yes
3	yes	no	no	no	no	no	yes	yes	yes
4	no	no	no	yes	no	no	no	yes	no
5	yes	no	no	no	yes	no	no	yes	no
6	no	no	no	no	yes	no	no	yes	no
7				no	yes	no	no	yes	no
8				no	no	no	no	no	no
9				yes	no	no			
10				no	yes	no			

Fig 60. Individual Performance for Y. checking whether individual's formants are in the range of average of data set plus minus deviation.

3.21 Letter Z

The formants generated during the pronunciation of the fricative sound of Z are depicted in Fig 61. F2 of the natives is demarcated to the right at around 2020 Hz and to the right at round 2450 Hz, and F1 from around 350 Hz up to 600 Hz. Additionally, like EM-2, EM-1 was delimited to the right by F2 at around 1980 Hz and to the left at around 2250 Hz, and the limit below for F1 was at around 570 Hz with upper limit at around 900 Hz. Besides, NEM-1 was confined in a region determined by F2 from 1800 to 2300 Hz, and F1 from 550 to 850 Hz. Consequently, the pattern read 'slightly back/open'.

The comparison of the set of data taken as groups, the statistical testing showed that the control group did not correlated with others for F1, but did come positive when compared with EM-2 for F2 only. The group of students were statistically similar for both F1 and F2 when paired up.

In fact, individual analysis showed that none of the students fell in the scope of the control group for F1 as depicted in Fig 63. As far as the range of F2 is concerned with, three elements of EM-2, two member of EM-1, and three from NEM-1 were accepted as in the range of control group.

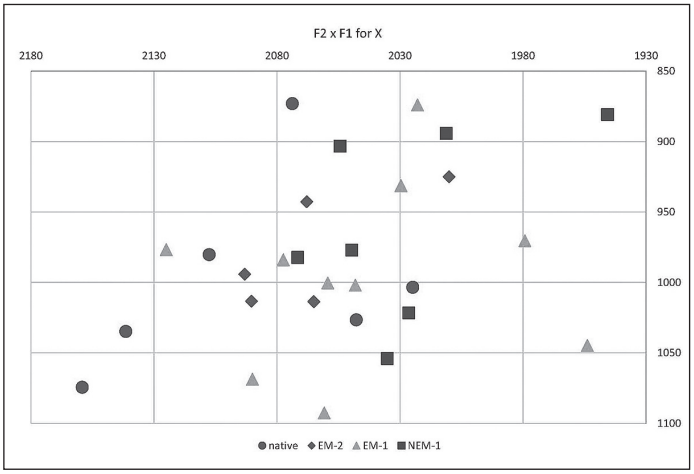

Fig 61. Graph of formants for Z. Horizontal axis: F2, vertical axis: F1.

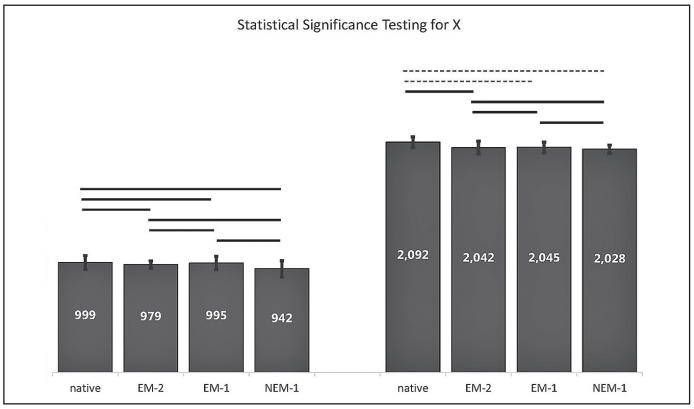

Fig 62. Statistical testing for Z. Left: F1. Right: F2. Dashed line: significant difference ($p<0.05$). Solid Line: not significant.

INDIVIDUAL ANALYSIS FOR Z
Benchmarking the distance between subject's formants and native data mean values of F2 and F1 against standard deviation (stdv) values

native data set	F2 mean	2239	F2 stdv	130	F1 mean	458	F1 stdv	66

data	EM-2			EM-1			NEM-1		
	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?	distance between F2 and mean F2 less than or equal F2 stdv?	distance between F1 and mean F1 less than or equal F1 stdv?	consider within the native's Fs range?
1	yes	no	no	no	no	no	no	no	no
2	yes	no	no	yes	no	no	no	no	no
3	no	no	no	no	no	no	yes	no	no
4	yes	no	no	no	no	no	no	no	no
5	no	no	no	no	no	no	no	no	no
6	no	no	no	yes	no	no	yes	no	no
7				no	no	no	yes	no	no
8				no	no	no	no	no	no
9				no	no	no			
10									

Fig 63. Individual Performance for Z. checking whether individual's formants are in the range of average of data set plus minus deviation.

4 DISCUSSIONS

Gathering the standard deviation values of the pronunciation for the formant F1, the result is as shown in Fig a. Note that the natives had large variations for some letters as D and Q. EM-2 had relatively small variations while EM-1 and NEM-1 bounced up and down depending on the letter. It means that in terms of 'openness / closeness' of the mouth, fresher students varied more than EM-2.

Focusing on the 'front / back' position in the mouth to produce the sound, Fig b shows that even the natives had a relatively large variation. The reason for this bouncing is predominantly due to a single outlier data that was included in the group of natives. However, this reasoning did not apply to NEM-1, which fluctuate larger than the other students. EM-2 and EM-1 behaved 'hand in hand', which suggested that these students tended to settle down similarly at some position along the front to back track.

In fact, Fig c shows that the students were likely to come with 'back' and 'open' in most of the cases. However, care has to be taken, because this is relative to North American English sounds.

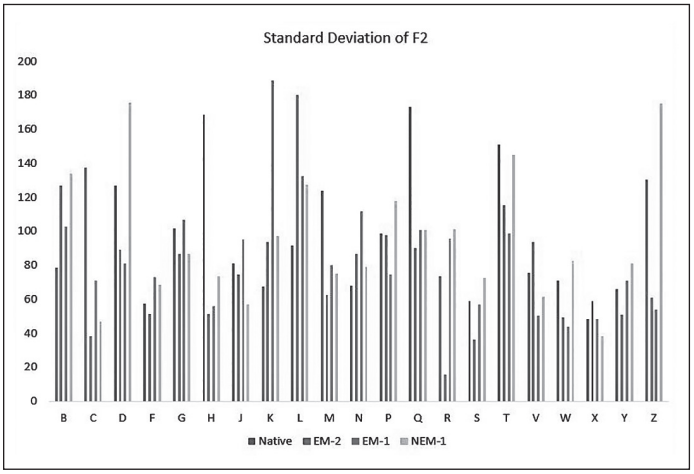

Fig a. Graph of standard deviations for F1.

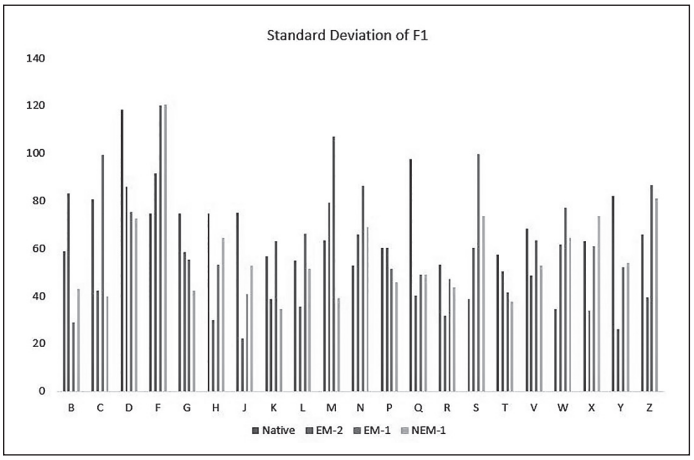

Fig b. Graph of standard deviations for F2.

Sound production position of the groups relative to the group of natives						
Letter	EM-2		EM-1		NEM-1	
	F2 (front/back)	F1 (open/close)	F2 (front/back)	F1 (open/close)	F2 (front/back)	F1 (open/close)
B	back	open	back	open	back	open
C	back	open	back	open	similar	open
D	back	open	back	similar	back	similar
F	front	similar	similar	similar	front	similar
G	back	similar	back	similar	back	similar
H	back	close	back	similar	back	close
J	back	similar	back	similar	back	similar
K	back	open	back	open	back	similar
L	front	open	front	open	front	close
M	front	open	front	open	front	similar
N	similar	open	similar	open	similar	open
P	back	open	back	open	back	open
Q	similar	similar	similar	similar	similar	similar
R	similar	open	similar	similar	similar	close
S	similar	open	front	open	front	similar
T	back	open	back	open	back	similar
V	back	open	back	open	back	open
W	front	open	front	open	similar	open
X	similar	similar	back	similar	back	similar
Y	front	open	front	open	front	similar
Z	similar	open	back	open	back	open

Fig c. Summary of the tendencies of students relative to native sounds.

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